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IS 6134-4 (1977): Methods of Measurement of Electrical Characteristics of Microwave Tubes, Part IV: Magnetrons  
[LITD 4: Electron Tubes and Display Devices]



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IS : 6134 ( Part IV ) - 1977

*Indian Standard*  
METHODS OF MEASUREMENT OF  
ELECTRICAL CHARACTERISTICS OF  
MICROWAVE TUBES  
PART IV MAGNETRONS

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# *Indian Standard*

## METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

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# *Indian Standard*

## METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

### PART IV MAGNETRONS

#### 0. FOREWORD

**0.1** This Indian Standard ( Part IV ) was adopted by the Indian Standards Institution on 26 May 1977, after the draft finalized by the Electron Tubes Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

**0.2** This standard ( Part IV ) shall be read in conjunction with IS : 6134 ( Part I/Sec 1 )-1971\*, IS : 6134 ( Part I/Sec 2 )-1972† and IS : 6134 ( Part II )-1973‡.

**0.3** While preparing this standard, assistance has been derived from the following documents issued by International Electrotechnical Commission :

IEC Pub 235-2 ( 1972 ) Measurement of the electrical properties of microwave tubes : Part 2 General measurements

IEC Pub 235-4 ( 1972 ) Measurement of the electrical properties of microwave tubes : Part 4 Magnetrons

IEC Pub 235-4A ( 1975 ) First supplement to Pub 235-4 ( 1972 )

**0.4** In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960§.

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#### 1. SCOPE

**1.1** This standard ( Part IV ) describes methods of measurement of electrical characteristics and related requirements and precautions applicable to all types of magnetrons.

\*Methods of measurement on microwave tubes : Part I General requirements, Section 1 General conditions and precautions for measurements.

†Methods of measurement on microwave tubes : Part I General requirements, Section 2 Common to all devices.

‡Methods of measurement on microwave tubes : Part II Oscillator tubes.

§Rules for rounding off numerical values ( revised ).

## **2. TERMINOLOGY**

**2.0** For the purpose of this standard, the terms and definitions given in IS : 1885 ( Part IV/Sec 3 )-1970\* and IS : 1885 ( Part IV/Sec 5 )-1972† shall apply.

## **3. GENERAL REQUIREMENTS AND PRECAUTIONS**

**3.0** In addition to the general requirements and precautions listed in IS : 6134 ( Part I/Sec 1 )-1971‡, the following requirements and precautions shall apply specifically to magnetrons.

### **3.1 Magnetic Field**

#### **3.1.1 *Integral ( Packaged ) Magnetrons***

**3.1.1.1** A magnetron is generally designed to minimize its size and weight. Hence, its permanent magnet is magnetised almost to its saturation value, and is liable to be demagnetized easily. Any of the following may cause appreciable loss of magnetization or distortion of the magnetic field or both, with resultant deterioration of tube performance :

- a) A sharp shock such as may result from an impact; and
- b) Gradual contact with, or proximity of, ferromagnetic materials.

**3.1.1.2** All ferromagnetic materials should, therefore, be kept entirely away, or at least at a minimum safe distance, from the magnetron.

**3.1.1.3** It is recommended that in installing such magnetrons and in executing other work near them, tools and accessories ( for example the magnetron mounting plate ) made only of non-ferromagnetic materials should be used.

**3.1.1.4** During storage, magnetrons should be separated by at least a minimum safe distance to prevent mutual interaction between their permanent magnets. They should be stored on non-ferromagnetic shelves. If ferromagnetic shelves are to be used, the tube should be separated from the ferromagnetic material by at least the minimum safe distance.

**3.1.1.5** The minimum safe distance is usually marked on the tube or specified in the ratings. If it is not designated, the maximum dimension of the magnet may be taken as the minimum safe distance.

\*Electrotechnical vocabulary : Part IV Electron tubes, Section 3 Microwave tubes.

†Electrotechnical vocabulary : Part IV Electron tubes, Section 5 Pulse terms.

‡Methods of measurement on microwave tubes: Part I General requirements, Section 1 General conditions and precautions for measurements.

### 3.1.2 Magnetrons with Separate Magnets

**3.1.2.1** To ensure the required homogeneity of the magnetic field between the pole pieces of the magnet, it is recommended that :

- a) the pole pieces of the magnet should have stated dimensions together with stated gap width;
- b) the pole pieces should have faces parallel within 1°, or as specified by the manufacturer;
- c) the pole pieces should be coaxial within 3 percent of the gap width or as specified by the manufacturer; and
- d) the pole pieces of the magnet should be made of soft magnetic material.

**3.1.2.2** Unless otherwise stated, the magnetic flux density should be within  $\pm 3$  percent of the stated nominal value. The magnetic flux density should be measured centrally over a small cross section, that is, located midway between the poles on the axes of the poles.

**3.1.2.3** The magnetron should be located between the pole pieces in such a way that its anode block is coaxial with the pole pieces and its cathode connection nearest to the north pole of the magnet, or in accordance with the manufacturer's instructions.

**3.1.3 Magnetic Field Supply** — A magnetron to be used with a specifically designed electromagnet is usually operated in one of the following ways :

- a) *Fixed-field operation* — In which the coil of the electromagnet is excited by external dc supply.
- b) *Series-field operation* — In which the coil of the electromagnet is connected in series with the anode and excited by an anode current passing through it.
- c) *Combined-field operation* — In which the coil of the electromagnet is excited by both anode current and an external dc supply.

Since each of these methods of operation has its own features and the performance of magnetron depends on the method used, a magnetron should be measured in the circuit specified in the manufacturer's instructions. For fixed-field operation, the existing current of the coil should be adjusted to a stated value, and for combined-field operation the internal resistance and/or open-circuit voltage of the external dc field supply should be adjusted to give a stated anode current. When the user wishes to make use of series-field or combined-field operation, the manufacturer's recommendations relative to the particular service should be followed, including the use of protective circuits for tube, coil and/or supply that are necessary to protect the tube in the event of coil flash-over, or the design of coils and circuits so as to prevent flash-over caused by current surges.

## IS : 6134 ( Part IV ) - 1977

**3.1.4** It is important to avoid positioning of any measuring instrument so near to the magnetron as to effect the accuracy of the instrument.

**3.2 Temperature Conditions** — The provisions of **5** of IS : 6134 ( Part I/ Sec 1 )-1971\* shall apply.

**3.3 Pressurizing** — The provisions of **6** of IS : 6134 ( Part I/Sec 1 )-1971\* shall apply.

**3.4 Radiation Dangers** — The provisions of **7** of IS : 6134 ( Part I/Sec 1 )-1971\* shall apply.

**3.5 Measuring Equipment** — The provisions of **4** of IS : 6134 ( Part I/ Sec 1 )-1971\* shall apply.

**3.5.1** The magnetron is connected to a load which satisfies stated conditions.

NOTE — When the stated conditions differ from the matched condition, the load may influence the measurements in particular measurement dealing with instability effects; also power and frequency.

**3.6 Heater Supply** — Immediately after, or within a stated interval after, the application of anode voltage, the heater current or voltage should be reduced in accordance with the stated heater schedule. The scheduled value should be maintained within  $\pm 5$  percent for voltage, or  $\pm 3$  percent for current, throughout the measurement unless otherwise specified.

NOTE — In magnetrons with filamentary cathodes and in which the heater power is very small compared with the anode input power, it may be necessary to use automatic compensation in order to keep the filament temperature constant.

**3.7 H.T. Supply** — After the heater has been energized and after the stated h.t. delay time, the anode voltage is applied and adjusted to provide a stated value of anode current.

**3.7.1** For pulsed magnetrons it is necessary that the shape of the anode voltage pulse satisfy the stated characteristics which should include:

- a) pulse duration,
- b) pulse repetition frequency,
- c) pulse rate of rise,
- d) pulse fall time, and
- e) spike

The following may also be stated:

- f) Pulse voltage drops and ripple,
- g) Post-pulse oscillation, and
- h) Back swing.

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\*Methods of measurement on microwave tubes: Part I General requirements, Section 1 General conditions and precautions for measurements,

**3.7.2** For pulsed magnetrons with indirectly heated cathodes, connect the negative line of the h. t. supply to the common cathode-heater terminal of the magnetron, to avoid damage to the heater. For the same reason, it is good practice to connect a capacitor of suitable value directly between the heater terminals.

**3.7.3** For CW magnetrons operated with dc voltage, the internal impedance of the h.t. supply should be as stated for the measurement and the percentage of ripple voltage should not exceed 3 percent unless otherwise specified.

**3.7.4** For CW magnetrons operated with ac or in filtered rectified voltage, the waveform of open circuit voltage and internal impedance of the h.t. supply, or the peak and mean value of the anode current, should be as stated.

**3.7.5 Pre-conditioning** — In order to ensure stable operation the magnetron shall be preconditioned first, by operating the magnetron at a reduced voltage, then increasing the voltage gradually till arcing occurs. When the arcing has subsided and the magnetron starts operating stably, the voltage shall again be increased until fresh arcing starts. This procedure shall be repeated until stable operation is reached.

**NOTE** — In new magnetrons and in magnetrons which have not been in use for sometime, a slight amount of gas may be present, which may give rise to excessive arcing and instability when the magnetron is put into operation at normal operating power.

## 4. METHODS OF MEASUREMENTS

**4.1 General Measurements** — These measurements are applicable to both pulsed and CW magnetrons.

**4.1.1 Mean RF Output Power** — The provisions of **4.1** of IS : 6134 ( Part I/Sec 2 )-1972\* shall apply.

### 4.1.2 Frequency

**4.1.2.1 General** — The provision of **5** of IS : 6134 ( Part I/Sec 2 )-1972\* shall apply.

**4.1.2.2 Spectrum width** — The provision of **5.1** of IS : 6134 ( Part I/Sec 2 )-1972\* shall apply.

**4.1.2.3 Minor lobe ratio** — Under consideration.

**4.1.3 Tuning** — The provisions of **6.1** to **6.6** of IS : 6134 ( Part I/Sec 2 )-1972\* shall apply.

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\*Methods of measurement on microwave tubes: Part I General requirements, Section 2 Common to all devices.

**4.1.3.1 Precautions** — Tuning measurements should be performed with matched load.

**4.1.4 Hysteresis** — The provision of **6.7.1** of IS : 6134 ( Part I/Sec 2)-1972\* shall apply.

**4.1.4.1 Precautions** — Hysteresis measurements should be made with matched load.

**4.1.5 Frequency Pulling Figure** — The provision of **4.1** of IS : 6134 ( Part II )-1973† shall apply.

**4.1.5.1 Precautions** — The impedance of the magnetron changes with the phase of the reflection coefficient. Therefore, the anode current should be approximately constant during the measurement.

**4.1.6 Frequency Pushing Figure** — The provision of **4.2** of IS : 6134 ( Part II )-1973† shall apply.

**4.1.7 Spurious Mode Oscillation** — The provision of **4.2** of IS : 6134 ( Part II )-1973† shall apply.

**4.1.8 Temperature Coefficient of Frequency** — The provisions of **4.3** of IS : 6134 ( Part II )-1973† shall apply.

#### **4.1.9 Runaway**

**4.1.9.1** The magnetron is coupled to a load having adjustable mismatch. The mismatch of the load is adjusted to a stated value of VSWR and the position of the associated voltage minimum is adjusted to obtain the minimum output power. The magnetron is operated with the stated supply voltage, and the change in anode current and/or power output is observed for a stated period of time, in order to determine whether runaway occurs or not.

**4.1.9.2** Runaway may be conveniently observed by means of an oscilloscope connected so as to display anode voltage and anode current.

**4.1.9.3** For the observation of runaway, especially in the case of CW magnetrons, the internal impedance of the power supply should not exceed a stated value.

#### **4.1.10 Moding**

**4.1.10.1** The magnetron is coupled to a load having an adjustable mismatch. The mismatch is adjusted to a stated minimum VSWR. With the magnetron operated under stated conditions, the phase of the reflection coefficient of the load shall be varied through  $2\pi$  radians. Moding is usually evidenced by an abrupt large change in (a) frequency and/or (b) voltage-current characteristics, and/or (c) power output.

\*Methods of measurement on microwave tubes: Part I General requirements, Section 2 Common to all devices.

†Methods of measurement on microwave tubes: Part II Oscillator tubes,

**4.1.10.2** For pulsed magnetrons, moding may be observed on a spectrum analyser. It is evidenced by missing lines in the output spectrum, together with double traces on an oscilloscope displaying detected r.f. output and anode current.

**4.1.10.3** If a sudden change does not occur, the phase of the reflection coefficient of the load is kept at the value for maximum output power (which is usually that most favourable to moding) and the magnetron is further observed for a stated period, if necessary, to see if a mode instability occurs because of, for instance, the decrease of cathode temperature.

#### **4.1.11** *Corona and Arcing*

**4.1.11.1** The purpose is to detect corona and arcing on magnetrons. Corona and arcing occur in connection with conducting surfaces which are not enclosed within the envelope of the magnetron.

**4.1.11.2** Operating conditions shall be as specified on the manufacturers individual specification sheet.

**4.1.11.3** Unless otherwise stated, the sequence of the procedure shall be as follows:

- a) The required anode voltage is applied to the magnetron in the test chamber.
- b) The pressure in the chamber is reduced to the required value and maintained at that value for at least 60 seconds during which there shall be no evidence of corona or arcing.

**4.1.11.4** *Arcing* — Arcs are recorded by a counter which is activated by an arc detector. The arc detector should be adjusted to respond to pulse current which rises to a specified value above normal operating pulse current. A measure of arcing is the number of arcs counted during a prescribed period under stated operating conditions.

**4.1.12** *Restarting Ability* — The magnetron is operated under stated conditions. After a steady state of operation is reached, the h.t. and heater supply voltages are turned off. After the magnetron has reached equilibrium in the cold state, all the supply voltages are again turned on in accordance with the stated procedure. A check is made to determine whether the anode current reaches a stated percentage of the original steady state value within the stated period.

**4.2 Pulsed Magnetron Measurements** — The following measurements (4.2.1 to 4.2.5) are applicable to pulsed magnetrons measurements in addition to those given in 4.1.

### 4.2.1 Pulse Characteristics

**4.2.1.1** The measuring devices should be so arranged that distortion introduced by their presence is negligible. In this measurement of the performance of a pulse modulated tube it is necessary to establish the characteristics of the applied voltage pulse, the pulse waveform of the current drawn by the tube and the envelope of the resulting output pulse.

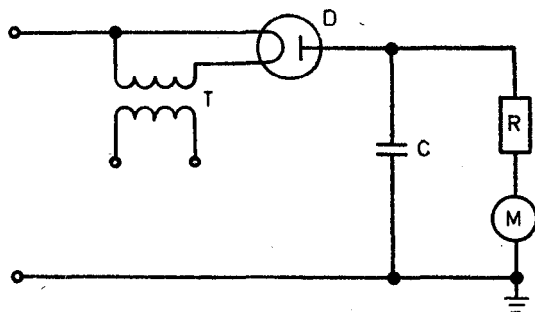
Because of the relative amplitudes of the current, voltage and output pulses depend on the nature of the electronic interaction, the pulse definitions applicable to the particular tube type should be used.

**4.2.1.2 Voltage pulse characteristics (applied)** — Measurement of the voltage pulse characteristics may be made by any suitable method, including either:

- a) peak diode voltmeter method, or
- b) CRO display method.

Both the methods may be used with the instrument connected directly across the circuit being measured or, where high voltages make this impracticable, a resistive or capacitive dividing network may be used. The choice of method will depend on the value of the peak voltage being measured and on the characteristics of the pulses as well as on the effect of the instrumentation, as part of the load, upon the supply.

**Method 1: Peak diode voltmeter method** — For measurement of the amplitude of repetitive pulses the peak diode voltmeter circuit as shown in Fig. 1 is recommended. The peak inverse voltage rating of the diode under pulsed conditions should exceed the maximum pulse voltage plus any backwing voltage which may occur. In general practice, the application of this method is limited to pulse voltages below approximately 35 kV.



NOTE — The connection of the diode should be in accordance with the polarity of the voltage being measured.

FIG. 1 CIRCUIT ARRANGEMENT FOR PEAK DIODE VOLTMETER METHOD

The diode should be chosen to have adequate current carrying capacity ( at its nominal heater voltage in case of a tube diode ). A high dynamic impedance of the diode may prevent full charging of the capacitors before the end of the pulse. In the case of a tube diode, the capacitive load on the pulse generator will be the capacitance of the diode plus the capacitance of the heater transformer, which should be suitably insulated to withstand the pulse voltage.

The time constant  $RC$  should be at least two orders of magnitude greater than the time between pulses. The resistor  $R$  should be chosen so that the load on the pulse generator is small and will usually have a value of many hundreds of megohms. The capacitor should have a voltage rating greater than the value of the pulse amplitude to be measured and, in order to reduce serious inductive effects, should be made up of an r.f. type of capacitor ( generally available only in small values ) in parallel with the main capacitor.

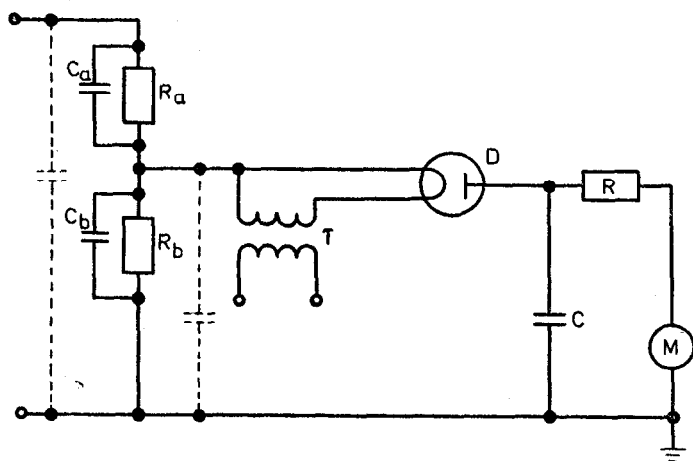
The circuit may be calibrated with a dc voltage or by a resistor of known value and accurately calibrated current meter. It is also recommended that the CRO display method be used to check against deformation of the pulse shape, which may introduce undesirable effects.

The extension of this method to voltages higher than about 35 kV is shown in Fig. 2 which uses a resistor divider network. The resistors  $R_a$  and  $R_b$  should be non-inductive and should be chosen so that the diode operates within its voltage rating. It may be necessary to insert capacitors  $C_a$  and  $C_b$  such that the time constants of the two sections of the divider are equal. The effective impedance of the diode circuit is in shunt with  $R_b$  and  $C_b$  during the pulse and its effect should be taken into account. In order to minimize the distortion of the pulse, the time constant of the input capacitance of the whole peak voltmeter circuit and its input resistance should be less than one-fourth of the pulse duration.

If a spike occurs on the voltage pulse, resistance should be added in series with the peak voltmeter ( see Fig. 3 ). The correct value of this resistance  $R_c$  can best be determined by observing the change in meter reading with increase in resistance ( see Fig. 4 ).

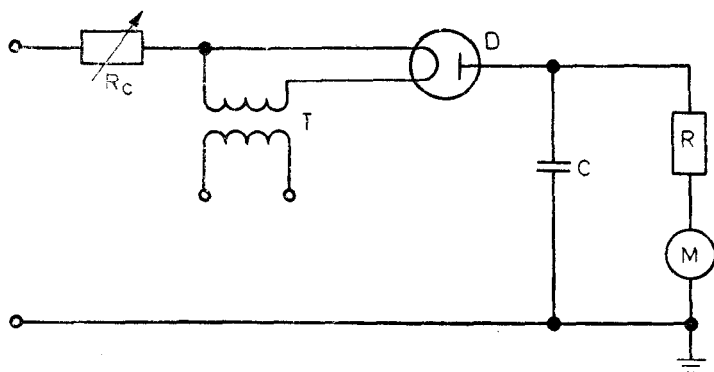
The accuracy may be improved if the components of the circuit and shunt used are enclosed in a dust-free, temperature-regulated compartment, with suitable mounting arrangements or oilbaths to avoid corona.

*Method 2: Cathode-ray oscilloscope ( CRO ) display method* — The CRO with a suitable divider, can be used to measure the characteristics of the pulse shape, for example, duration, rise time, fall time and amplitude.



$D$  = Diode whose ratings are suitable for the voltage appearing across  $R_b$   
 $R_a, R_b$  = Voltage divider  
 $C_a, C_b$  = Capacitors added such that  $R_a C_a = R_b C_b$

FIG. 2 CIRCUIT ARRANGEMENT FOR PEAK DIODE VOLTMETER METHOD (HIGH VOLTAGE)



NOTE — The connection of the diode should be in accordance with the polarity of the voltage being measured.

FIG. 3 ALTERNATIVE CIRCUIT ARRANGEMENT FOR PEAK DIODE VOLTMETER METHOD

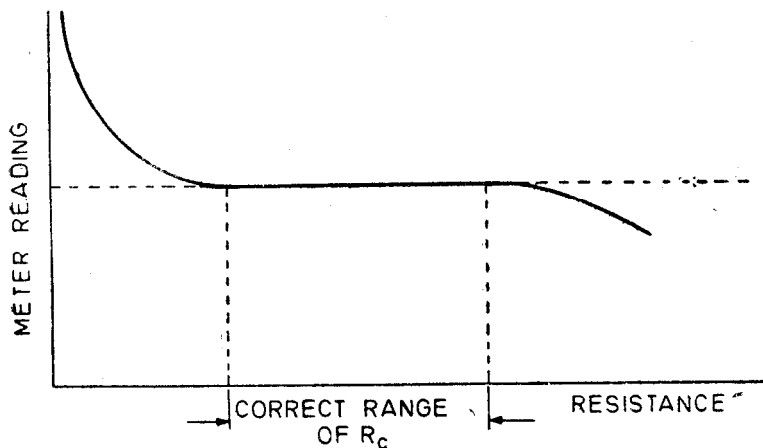


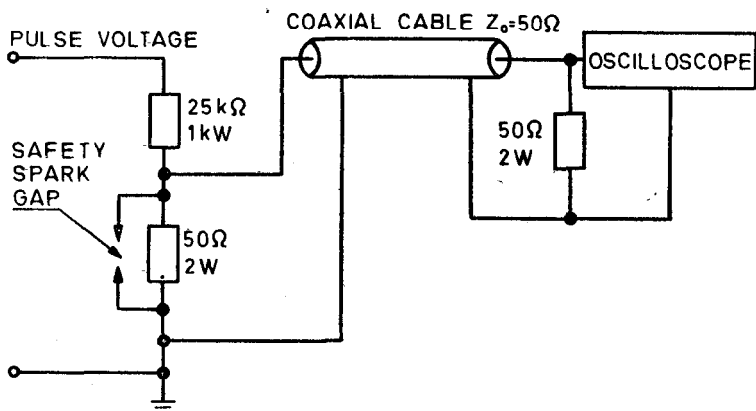
FIG. 4 CORRECT VALUE OF RESISTANCE FOR REMOVAL OF VOLTAGE SPIKE

Details of suitable divider circuits are as follows:

- a) *Resistive divider circuit* (see Fig. 5) — The total resistance should be kept low enough to avoid errors caused by the input capacitance of the CRO; in general, the total resistance should not be higher than 40 000 ohms. Preferred range is 10 000 ohms to 25 000 ohms. The dissipation within the divider network is higher than would be expected when assuming a flat top pulse and a factor of 2.5 times the expected dissipation is recommended. Care should be taken to reduce the effects of inductance by the use of suitable resistors (for example, deposited film carbon resistors) and of corona by the use of suitable mounting arrangements or oil-baths where required.

The connecting cable to the CRO should be matched at both ends in order to avoid distortion in the display. When this cannot be done a resistance must be added in series with the sending end of the cable. A suitable spark gap should be included in order to protect the operator and the CRO from high voltage if the divider network becomes open-circuited.

NOTE — It is generally suitable for pulse length between 0.5 to 10 micro-seconds and duty cycles of the order of 0.001. The method is not suitable for testing low power pulse tube because the additional loading on the modulator is excessive.



NOTE — Numerical values shown are illustrative only.

FIG. 5 CIRCUIT ARRANGEMENT FOR OSCILLOSCOPE DISPLAY METHOD WITH RESISTIVE DIVIDER NETWORK

- b) *Capacitive divider circuit* (see Fig. 6) — This is particularly useful at very short pulse durations. Its use for longer pulse durations is restricted by the amount of pulse drop which can be tolerated.

The divider is made up of a capacitor  $C_1$  developing a high voltage in series with a capacitor  $C_2$ , developing a low voltage; the divider ratio being approximately inversely proportional to the ratio of the capacitances. The divider network is connected to the CRO through a series matching resistor  $R$ , a coaxial cable and, if necessary, a blocking capacitor  $C_3$ . The input resistance of the CRO should be two or three orders of magnitude larger than  $R$ . The capacitor  $C_1$  has a value usually in the range of 1 to 10 pF and should be shielded to avoid stray pick-up. The dielectric may be ceramic, resin, oil or vacuum, as required by the working voltage. The capacitor  $C_2$  should have very low inductance and a safety spark gap should be connected across this capacitor. The divider circuit may be calibrated using other methods described, for example the resistive divider or peak voltmeter method within its range, using a suitable pulse duration and with the errors caused by the known characteristics of the methods minimized.

For pulse durations down to about 0.05 microsecond the length of the coaxial cable should not exceed that which has a two-way transit time of about one-tenth of the pulse duration. For pulse durations below about 0.05 microsecond the cable length becomes impracticably short and the divider may then be mounted directly on the CRO.

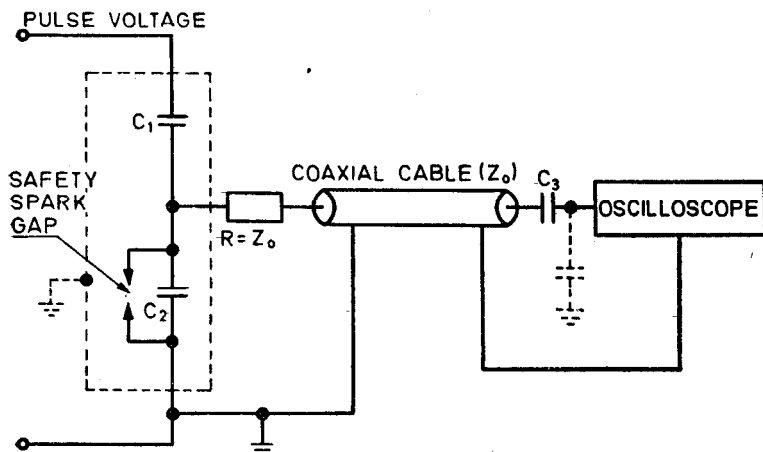


FIG. 6 CIRCUIT ARRANGEMENT FOR OSCILLOSCOPE DISPLAY  
METHOD WITH CAPACITIVE DIVIDER NETWORK

- c) *Balanced divider circuit* (see Fig. 7) — This is particularly useful when the pulse waveform is to be faithfully reproduced in details.

The divider consists of a high voltage section  $R_1$  and  $C_1$  and a low voltage section  $R_2$  and  $C_2$  and the CRO matching components. The time constants of each section including the effects of stray impedances must be equal. Usually the value of  $R_2$  is made equal to the characteristic impedance of the coupling line between the divider network and the CRO. In this case the resistance  $R_3$  in the diagram is zero and  $R_4 = R_2$ . This gives a division ratio  $2R_1/R_2 = C_2/C_1$ . The time constant of the two circuits are  $R_1C_1$  and  $\frac{1}{2}R_2C_2$  respectively.

When available equipment requires that the value of  $R_2$  be less than the connector cable impedance  $Z_0$ , and additional nonreactive resistor  $R_3$  must be added at the sending end of the cable. The division ratio is:

$$\frac{R_2 R_4}{R_1 (R_2 + R_3 + R_4) + R_2 (R_3 + R_4)}$$

The time constants are then,  $R_1C_1$  and  $R'C_2$

where

$$R' = \frac{R_2 (R_3 + R_4)}{(R_2 + R_3 + R_4)}$$

It is difficult to use this circuit when  $R_2$  exceeds  $Z_0$  of the cable.

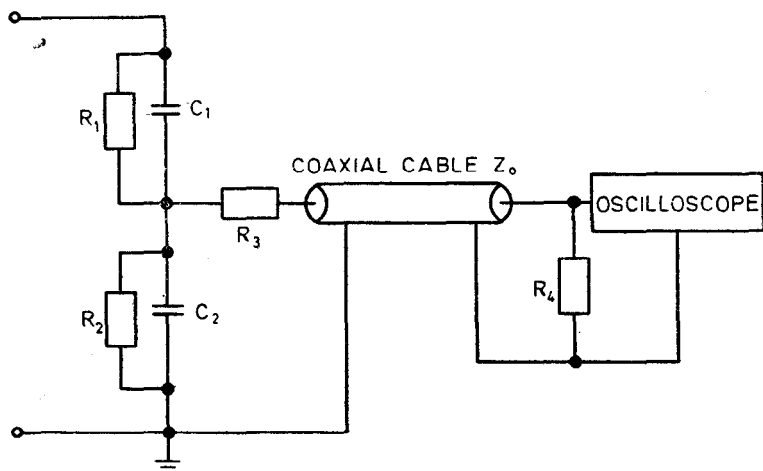


FIG. 7 CIRCUIT ARRANGEMENT FOR OSCILLOSCOPE DISPLAY  
METHOD WITH BALANCED DIVIDER NETWORK

When assembled, the divider is checked for division ratio and for pulse distortion caused by possibly overlooked stray impedance effects. This may be done using a calibrated square wave generator whose rise and fall time characteristics are similar to those of the pulse to be measured.

Alternatively, calibrated signal sources in the frequency range extending from zero up to twice the reciprocal of the pulse duration may be used.

NOTE — In practice it may be useful to isolate the divider network from the cable and the CRO by using a value of  $R_3$  several times greater than  $Z_0$ .

**4.2.1.3 Rate of rise voltage pulse** — The rate of rise of voltage pulse can be measured by any of the following two methods.

*Method 1: Capacitive divider circuit* — This method makes direct use of capacitive divider circuit given in Method 2 of 4.2.1.2 using the minimum possible value of  $C_1$  consistent with:

- a) the provision of an adequate deflection potential to be supplied to the oscilloscope;
- b) minimum capacitive loading of the pulse source; and

- c) freedom from unwanted inputs due to stray capacitive pick-up. ( Capacitor  $C_1$  should be shielded so as to minimize this effect. )

Provided that these precautions are taken, the measured rate-of-rise of voltage pulse is not materially different from that when the measurement equipment is not connected to the pulse source.

The rate-of-rise can be determined by direct measurement of the displayed pulse.

NOTE — A large value of  $C_1$  reduces the rate-of-rise of voltage. In extreme cases it may be desirable to measure the rate-of-rise of voltage pulse at various values of  $C_1$  so that an extrapolation to zero capacitance can be accomplished.

### Method 2 — Differentiator circuit

#### Theory

Since the rate-of-rise of pulse voltage is defined mathematically by a derivative representing a change of pulse quantity with respect to time, a differentiating circuit may be used ( see Fig. 8 ).

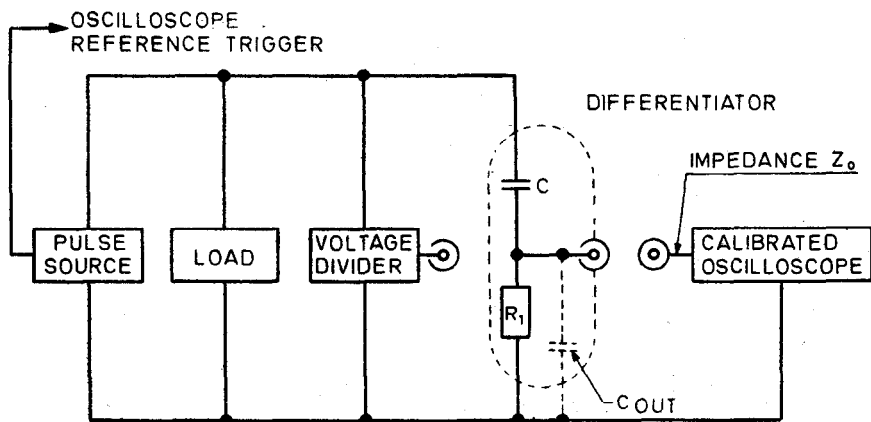


FIG. 8 METHOD 2: DIFFERENTIATING CIRCUIT

The differentiating element consists of a capacitor  $C$  and a resistor  $R_1$ , the output of which is viewed on an oscilloscope having a calibrated line display and associated metering system.

Subject to certain restrictions, the rate-of-rise of the voltage pulse can be found from the voltage output  $V$  of the differentiator by means of the following relation:

$$\frac{dv}{dt} = \frac{V_o}{RC}$$

where  $C$  is the capacitance of the differentiator and  $R$  is the resultant resistance of the parallel combination and  $R_1$  and the resistance of the matching network to the transmission line.

The restrictions are as follows:

- a) The differentiator time constant  $R (C + C_{out})$  must be much smaller than the pulse rise time, one-tenth or less; and
- b) The reactance of the differentiator capacitance  $C$  must be high relative to the output impedance of the pulse source and the load combined, at all frequencies up to the reciprocal of the pulse rise time.

NOTE — In practical case, the transmission line to the oscilloscope will effect the differentiating network. The effect will be minimized by using  $R_1 = Z_0$ .

In order to prevent the problems arising from reflections, it is recommended that both end of the line be matched, in which case:

$$\frac{dv}{dt} = \frac{2V_0}{R_1 C}$$

### Measurement

The measuring equipment is arranged so that the output of the voltage divider and the output of the differentiator can be displayed on a calibrated oscilloscope ( see Fig. 8 ).

The rate-of-rise of the voltage pulse at a stated voltage level can then be calculated by use of the formula given in 4.2.1.3 ( Method 2 ).

**Precautions** — The following precaution shall be taken:

- a) All the cables in the system should be matched at both ends;
- b) In order to select the voltage level at which to measure the rate-of-rise it is necessary to synchronize the display of the derivative  $dv/dt$ , and the leading edge of the pulse being measured; and
- c) The oscilloscope must be such that the time base is stable and is not triggered by extraneous causes. Its band-width must be sufficient to allow the pulse and the derivative to be displayed without linear distortion, and the resolution must be adequate to allow accurate measurement.

**4.2.1.4 Current-pulse characteristics** — Pulse amplitude, pulse duration, ripple on the pulse, time of rise and time of fall of the current pulse can be measured by displaying the current pulse on an oscilloscope in either of the recommended circuits shown in Fig. 9 and 10.

The current-viewing resistor  $R$  in Fig. 9 should be designed and constructed with special precautions to achieve negligible inductance. The value of the resistor  $R$  should be sufficiently small so that capacitance between the external waveguide and earth does not modify the wave shape.

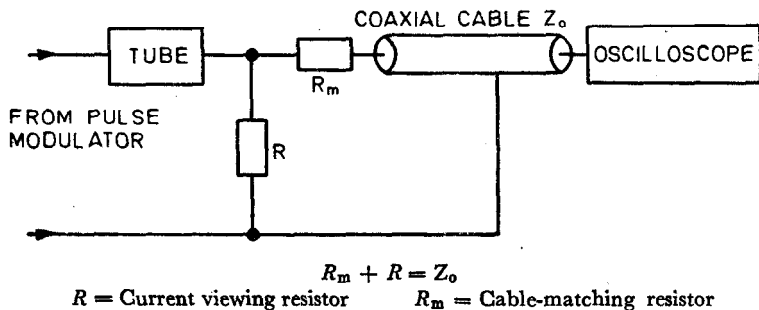


FIG. 9 CIRCUIT FOR OBSERVATION OF CURRENT PULSE

The stray capacitance of the current transformer in Fig. 10 should be sufficiently small so that the observed waveform of the pulse is not modified from the original. Care should be taken to avoid unwanted voltages caused by stray fields.

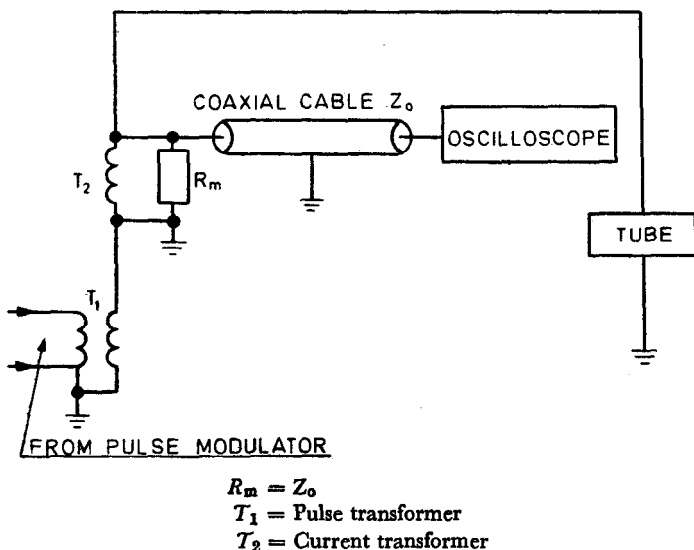


FIG. 10 ALTERNATIVE CIRCUIT FOR OBSERVATION OF CURRENT PULSE

**4.2.1.5 R.F. output pulse characteristics** — The envelope of the output pulse is obtained by means of a calibrated microwave detector, of suitable bandwidth which is coupled to the output circuit of the tube. When short pulses are being viewed, it is necessary to ensure that the detector bandwidth is adequate. In order to derive the correct value of pulse duration

for the calculation of pulse output power; a square law detector should be used. Then the duration, measured at the instants at which the instantaneous values of the pulse equal 50 percent of the pulse amplitude, is used to calculate the duty factor.

If a linear detector is used, the pulse duration is measured between the instants at which the instantaneous values of the pulse equal 70·7 percent of the pulse amplitude.

**4.2.1.6 Pulse repetition frequency**— This measurement should be made with the greatest possible accuracy in view of its effect on other associated measurements. When ancillary equipment is used this should be checked against standards.

It is preferable to measure the pulsed r.f. by using pulses from the tube being but when this cannot be done, the correspondence of these pulses with those used for measurement should be checked.

**Method 1**— The pulses are counted, using for example a decade counter, and timed with a stop-watch or a crystal-controlled timing device. The maximum counting rate of the counter should exceed the p.r.f. and the counter should have a register that will hold a count corresponding to a period that can be timed with good accuracy. The pulse amplitude and duration should be such as to make the counter operate properly and it may be necessary therefore to obtain pulses for this purpose from one of the driving stages of the tube being measured. Typical accuracy to be expected with a stop-watch can be better than 1 percent, but with a crystal-controlled timing device the accuracy can be  $\pm 1$  pulse per counting interval.

**Method 2**— The modular may be driven by an external calibrated oscillator.

**Method 3**— The interval between successive pulses is measured using the calibrated time base of an oscilloscope. It is recommended that the frequency of the calibration wave be not less than 25 times the p.r.f. so that the visual interpolation meets the required accuracy. The trace should be examined by time base expansion to ensure that the reference frequency has been set up to an exact integral sub-multiple of the p.r.f. being measured. When the calibration frequency has been correctly adjusted no trace will appear across the base of the displayed pulses.

**4.2.1.7 Duty factor**— The duration of the 'on' active condition is measured by means of a suitably calibrated oscilloscope (see 4.2.1.2, 4.2.1.4 and 4.2.1.5 as appropriate). The total number of 'on' active conditions which occur over a required period, termed the averaging period, is obtained by use of an accurate counting system. The duty factor is then derived from the quotient of the summation of the 'on' active condition periods occurring during the averaging period, by the averaging period.

For the observation of the total number of 'on' active condition periods, the provisions of 4.2.1.6 may be applied.

It is desirable that the duty factor be maintained as near as possible to the stated value. If small discrepancies of pulse duration introduce deviations outside this accuracy, compensation may be effected by adjustment of the pulse repetition frequency.

#### 4.2.2 Incidental FM

4.2.2.1 During operation of the magnetron, the spectrum is observed on spectrum analyser.

4.2.2.2 If incidental f.m. exists, the spectrum envelope will show a modulation as in Fig. 11A or partial moding as shown in Fig. 11B, or twinning as shown in Fig. 11C.

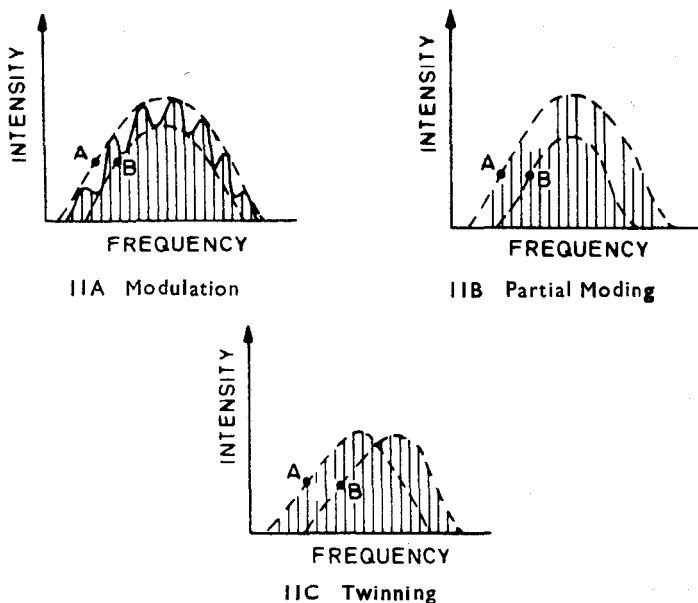


FIG. 11 SPECTRUM ENVELOPE

4.2.2.3 Incidental f.m. is measured as the frequency difference (the distance  $AB$  in Fig. 11) between the curve that passes through every peak of the spectrum envelope and that which passes through every valley.

4.2.2.4 Since this value includes f.m. of the analyser, the analyser should be checked against the output of a CW generator known to be free of f.m. The inherent incidental f.m. of the analyser should be subtracted

from the value measured above. The modulator output should also have pulse-to-pulse ripple and amplitude jitter less than stated values unless otherwise stated, this measurement should be performed under normal operating conditions.

**4.2.3 Pulse Output Power** — Provisions of 4.2 of IS: 6134 ( Part I/Sec 2 )-1972\* shall apply.

**4.2.4 Peak Envelope Power ( Peak Output Power )** — Provisions of 4.3 of IS: 6134( Part I/Sec 2 )-1972\* shall apply.

**4.2.5 Pulse Stability** — Provisions of 6 of IS: 6134 ( Part II )-1973† shall apply.

**4.3 CW Magnetron Measurements** — The following measurements ( 4.3.1 to 4.3.8 ) are applicable to pulsed magnetrons measurements in addition to those given in 4.1.

**4.3.1 Minimum Output Power at Mismatched Load** — With the magnetron operated under stated conditions, the output power is measured with a mismatched load having a stated VSWR and phase adjusted to give minimum output power. This minimum output power is measured.

**NOTE** — A CW magnetron designed for dielectric heating is often operated with highly mismatched load.

**4.3.2 Output Power in a Condition of Practical Application** — The purpose of this measurement is to evaluate the output power of a magnetron designed for dielectric heating under a condition of practical application. The magnetron is installed in a specified heating equipment.

**4.3.2.1 Method 1** — A specified vessel, filled with clean water of stated quantity or flowing at a stated rate, is placed at a stated position in the heating chamber. With the magnetron operating under stated conditions for a stated time, the temperature rise of the water is measured by means of a thermometer or other suitable device.

The output power is calculated by the following formula:

$$P = 4.186 \frac{\Delta t V}{T}$$

where

$P$  = output power in watts;

$\Delta t$  = temperature rise of water, in °C;

$V$  = volume of water in m<sup>3</sup>, and

$T$  = time of magnetron operation in seconds.

\*Methods of measurement on microwave tubes: Part I General measurements, Section 2 Common to all devices.

†Methods of measurements on microwave tubes: Part II Oscillator tubes.

**4.3.2.2 Method 2** — The specified vessel of Method 1 may be replaced by a specified water load having a stated flow rate. The power output is calculated according to the calorimetric method [ see 4.1.1 of IS: 6134 ( Part I/Sec 2 )-1972\* ].

**NOTE** — It is desirable to keep the upper temperature sufficiently low so that steam losses will not significantly invalidate the measurement.

**4.3.3 Incidental F.M. ( Self Generated F.M. )** — A portion of the output power is coupled into a spectrum analyser whose sweep rate is either very fast or very slow relative to the modulation rate to be observed. For CW observation using a wave-meter, it may be convenient to set the sweep frequency close to the coherent modulation frequency. The difference between the extremes of the frequency excursions observed is the incidental ( self generated ) f.m.

**4.3.4 Noise** — Under consideration.

**4.3.5 Emission Stability** — The provision of 4.5 of IS: 6134 ( Part I/Sec 2 )-1972\* shall apply.

**4.3.5.1** Moding as well as power and frequency should be determined.

**4.3.6 Frequency Sensitivity to Electrode Voltage Variation ( Voltage Coefficient of Frequency )** — The provision of 5.2.1 of IS: 6134 ( Part I/Sec 2 )-1972\* shall apply.

**4.3.7 Heater Modulation Effect** — The provision of 8 of IS: 6134 ( Part I/Sec 2 )-1972\* shall apply.

**4.3.8 Voltage at Reduced Current**

**4.3.8.1** The heater voltage or current for this measurement should be set at the values specified for standby conditions.

**4.3.8.2** The anode voltage is increased gradually from zero until the required value of anode current is reached. This anode current is chosen to be a small percentage ( usually 5 to 10 percent ) of the full operating anode current. The amplitude of the anode voltage is then measured.

**NOTE** — This measurement is substituted for one dealing with starting, which is subjective because the start of oscillation is difficult to detect. The measurements should be made in accordance with the manufacturer's instructions as some magnetrons may require special cathode programming to avoid destruction arising from excessive back-heating during the measurement.

**4.4 Voltage Tunable Magnetron Measurements** — The following measurements ( 4.4.1 and 4.4.9 ) are applicable to voltage tunable magnetron in addition to those given in 4.1 and 4.3 except 4.1.3 and 4.1.4.

\*Methods of measurement on microwave tubes: Part I General measurements, Section 2 Common to all devices.

**4.4.1 Voltage Tuning Range** — The magnetron is adjusted to operate at the reference frequency under optimum conditions. The anode voltage only is varied, so as to obtain frequencies both above and below the reference frequency. The frequencies at which the power is a stated percentage of the maximum is noted. The result of the measurement is the difference between these frequencies.

**4.4.2 Tuning Rate or Tuning Speed** — Provisions of **6.5** of IS : 6134 ( Part I / Sec 2 )-1972\* shall apply.

**4.4.3 Noise** — Under consideration.

**4.4.4 Voltage Tuning Sensitivity**

**4.4.4.1** The tuning sensitivity may be obtained from a measurement of frequency change with a stated variation of the tuning control ( mechanical or electronic ) or, alternatively, as a measurement of tuning control variation for a stated frequency change.

**4.4.4.2** As the tuning sensitivity is not necessarily uniform over the required tuning range, it is recommended that an indication be given as to which part of the range is used in making the measurement, for example, a stated frequency spread centred at the half-power point, over the linear range or in the small-signal range.

**4.4.5 Voltage Tuning Non-linearity** — For this measurement, the frequency of oscillation is varied electronically over a small amplitude ( for example, approximately 4 percent of the modulation range ) and the frequency deviation is measured by means of a suitable f.m. receiver ( or spectrum analyzer ). The oscillation frequency is slowly swept by varying the direct voltage applied to the frequency controlling electrode while the small superimposed modulating voltage is maintained constant. The deviation at the centre frequency  $S_0$  and the maximum change in frequency deviation  $\Delta S$  occurring over the swept range are noted. The ratio  $\frac{\Delta S}{S_0}$  is a measure of the electronic tuning non-linearity.

**4.4.6 Tuning Discontinuities** — In measuring tuning discontinuities, the frequency or power is measured over the frequency tuning range with an instrument of suitable resolution or precision. An abrupt change greater than a stated value shall be considered a discontinuity.

**4.4.7 Frequency-Pushing Figure** — This is measured by varying the electrode current periodically under the stated operating conditions. The difference between the extremes of frequency of oscillation throughout the stated current variation is measured. The frequency-pushing figure is computed as the ratio of this difference in frequency, to the magnitude of the current variation.

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\*Methods of measurement on microwave tubes : Part I General measurements, Section 2 Common to all devices.

**4.4.8 Electric Tuning Hysteresis**— The tube should be operated under stated conditions at the reference frequency. The electronic tuning control voltage is varied by the application of a suitable ac sweep voltage of a stated amplitude and frequency.

**4.4.8.1 Power hysteresis**— The output power of the tube is examined as a function of the electronic tuning control voltage. The power obtained as the voltage is increased, is compared with the power obtained as the voltage is decreased.

**4.4.8.2 Degree of power hysteresis**— The result of measurement may be expressed in two ways as follows:

- a) The maximum degree of power hysteresis within a stated swept range of the controlling parameters. The ratio between the maximum degree of power hysteresis expressed, as a difference, within a stated swept range and the maximum power within that range, the result being expressed as a percentage.
- b) The power ratio for stated degree of power hysteresis. The ratio between the highest power at which a stated degree of power hysteresis is reached as hysteresis increases and the maximum power within the swept range, the result being expressed as a percentage or in dB.

**4.4.8.3 Range of power hysteresis**— This is expressed as the ratio between the electronic tuning voltage range over which a stated degree of power hysteresis is exceeded and a stated part of the sweep voltage range (for example, in reflex klystrons, the voltage range which provides oscillation over the full mode; in backward wave oscillators, the voltage range required for tuning between stated frequencies). The result is expressed as a percentage.

**4.4.9 Frequency Hysteresis**— The frequency of oscillation of the tube is examined as a function of the electronic tuning control voltage, the frequency obtained as the voltage is increased being compared with the frequency obtained as the voltage is decreased.

**4.4.9.1 Degree of frequency hysteresis**— This is measured as the absolute value of the difference at a stated voltage between the frequency obtained as the voltage is increased and the frequency obtained as the voltage is decreased, the result being expressed in frequency units.

**4.4.9.2 Range of frequency hysteresis**— This is measured as the ratio between the electronic tuning voltage range over which a stated degree of frequency hysteresis is exceeded and a stated part of the sweep voltage range, the result being expressed as a percentage.

**INDIAN STANDARDS**  
**ON**  
**MICROWAVE TUBES**

IS:

- 1885 (Part IV/Sec 1)-1973 Electrotechnical vocabulary: Part IV Electron tubes,  
Section 1 Common terms (*first revision*)
- 1885 (Part IV/Sec 3)-1970 Electrotechnical vocabulary: Part IV Electron tubes,  
Section 3 Microwave tubes
- 1885 (Part IV/Sec 6)-1972 Electrotechnical vocabulary: Part IV Electron tubes,  
Section 6 Noise in microwave tubes
- 2032 (Part XIII)-1971 Graphical symbols used in electrotechnology: Part XIII  
Microwave tubes
- 5323-1969 Letter symbols and abbreviations for electron tubes
- 6134 (Part I/Sec 1)-1971 Methods of measurement on microwave tubes: Part I General  
measurements, Section 1 General conditions and precautions for measure-  
ments
- 6134 (Part I/Sec 2)-1972 Methods of measurement on microwave tubes: Part I General  
measurements, Section 2 Common to all devices
- 6134 (Part II)-1973 Methods of measurement on microwave tubes: Part II Oscillator  
tubes
- 6134 (Part III)-1973 Methods of measurement on microwave tubes: Part III Amplifier  
tubes
- 8441-1977 Methods of measurements on incidental X-radiation from electron tubes